(15)

AFGL-TR-81-0237

SIO Ref. 81-33

LEVEL II

AD A108879

SPRING AND FALL MEASUREMENTS OF EUROPEAN VERY LOW ALTITUDE VOLUME SCATTERING COEFFICIENTS

Richard W. Johnson

Approved for public release; distribution unlimited.

Scientific Report No. 17
August 1981

Contract No. F19628-78-C-0200
Project No. 7670
Task No. 7670-14
Work Unit No. 7670-14-01

Contract Monitor, Major John D. Mill, USAF
Optical Physics Division

Prepared for
Air Force Geophysics Laboratory, Air Force Systems Command
United States Air Force, Hanscom AFB, Massachusetts 01731

DTIC FILE COPY

UNIVERSITY OF CALIFORNIA SAN DIEGO

SCRIPPS INSTITUTION OF OCEANOGRAPHY

VISIBILITY LABORATORY La Jolla, California 92093

22083

Qualified requestors may obtain additional copies from the Defense Documentation Center. All others should apply to the National Technical Information Service.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: AFGL-TR-81-0237 — 2. GOVT ACCESSION NO.: AD-A108 879	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): SPRING AND FALL MEASUREMENTS OF EUROPEAN VERY LOW ALTITUDE VOLUME SCATTERING COEFFICIENTS	5. TYPE OF REPORT & PERIOD COVERED: Scientific - Interim Scientific Report No. 17 6. PERFORMING ORG. REPORT NUMBER: SIO Ref. 81-33
7. AUTHOR(s): Richard W. Johnson	8. CONTRACT OR GRANT NUMBER(s): F19628-78-C-0200
9. PERFORMING ORGANIZATION NAME AND ADDRESS: University of California, San Diego Visibility Laboratory La Jolla, California 92093	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62101F 7670-14-01
11. CONTROLLING OFFICE NAME AND ADDRESS: Air Force Geophysics Laboratory Hanscom AFB, Massachusetts 01731 Contract Monitor: Major John D. Mill/OPA	12. REPORT DATE: August 1981 13. NUMBER OF PAGES: 18
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Atmospheric Scattering Coefficient
Surface Visibility
Slant Path Contrast Transmittance

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents measurements of atmospheric volume scattering coefficients collected during twenty-five low altitude flights made mostly during the Spring and Fall seasons of 1976 and 1977 at four different European locations. The measurements were conducted during an instrumented aircraft's final approach and landing at its staging airbase. The measurements were made using a pseudo-photopic spectral response and thus are suitable for comparison with data associated with standard visual determinations of airfield visibility.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT continued:

The data illustrate that in twenty-two of twenty-five cases, there was little or no significant variation in the value of scattering coefficient as the aircraft approached the surface from an altitude of several hundred meters.

AFGL-TR 81 0237 SIO Ref. 81-33

SPRING AND FALL MEASUREMENTS OF EUROPEAN VERY LOW ALTITUDE VOLUME SCATTERING COEFFICIENTS

Richard W. Johnson

Visibility Laboratory
University of California, San Diego
Scripps Institution of Oceanography
La Jolla, California 92093

Approved:

Roswell W. Austin, Director
Visibility Laboratory

Approved:

William A. Nierenberg, Director
Scripps Institution of Oceanography

CONTRACT NO. F19628-78-C-0200
Project No. 7670
Task No. 7670-14
Work Unit No. 7670-14-01

Scientific Report No. 17
August 1981

Contract Monitor
Major John D. Mill, Atmospheric Optics Branch, Optical Physics Division

Approved for public release; distribution unlimited.

Prepared for

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

SUMMARY

This report, which describes portions of the Visibility Laboratory's Project OPAQUE effort, was prepared under AFGL Contract F19628-78-C-0200. It contains a presentation of 25 low altitude scattering coefficient profiles and related meteorological data that were measured mostly during the Spring and Fall seasons of 1976 and 1977 at four different geographical locations. The measurements were conducted during an instrumented aircraft's approach and landing at four of the staging bases associated with the overall OPAQUE program, Johnson *et al.* (1979). Similar data covering the Winter and Summer seasons of 1978 have been presented in an earlier report, AFGL-TR-81-0154, Johnson (1981a).

The nephelometer measurements of total volume scattering coefficient which are presented in this report were made using a pseudo-photopic spectral response having a mean wavelength of 557nm, and are thus suitable for comparison with data associated with standard visual determinations of airfield visibility. The temperature and dewpoint temperature measurements were made using an AN/AMQ-17 aerograph and a Cambridge Model 137-C3 Aircraft Hygrometer System. Measurements of horizon and terrain luminances which were also made during these aircraft descents are not included in this report, but are available in the Visibility Laboratory's basic data base should their subsequent analysis become desireable.

The reported data illustrate that in twenty-two out of twenty-five cases, there was little or no significant variation in the photopic scattering coefficient as one approaches the surface from an altitude of several hundred meters. Thus modelling approximations of low altitude haze properties based upon near surface measurements are in general appropriate for the range of meteorological conditions extant during these flights.

TABLE OF CONTENTS

SUMMARY v

LIST OF ILLUSTRATIONS ix

1. INTRODUCTION 1

2. PROCEDURES & INSTRUMENTATION 2

3. WEATHER SUMMARY 3

4. DATA PRESENTATION 6

    4.1 Data and Flight Summary 6

    4.2 Description of Data Tables & Graphs 6

    4.3 Supplementary Data Entries 6

5. DATA DISCUSSION 10

    5.1 Summary 11

6. ACKNOWLEDGEMENTS 11

7. REFERENCES 11

APPENDIX A: Meteorological Glossary & Abbreviations 13

APPENDIX B: VisLab Contracts & Related Publications 14

LIST OF TABLES AND ILLUSTRATIONS

Table No.		Page
1.1	Flight Identification Data	1
2.1	Geographical & Seasonal Distribution of Low Altitude Scattering Coefficient Profiles	2
3.1	Comparison of Aerodrome & C-130 Data Differences	4
3.2a	Standard Meteorological Table, Wunstorf, Germany	4
3.2b	Standard Meteorological Table, Vaerlose, Denmark	5
3.2c	Standard Meteorological Table, Mildenhall, England	6
3.2d	Standard Meteorological Table, Lorient, France	6
5.1	Summary of Conditions for Flights Profiles Illustrating Low Altitude Haze Structure	10
5.2	Comparison of Station Reported Visibilities and Nephelometer Derived Visual Ranges	11

Fig. No.		Page
2-1	Typical OPAQUE Flight Tracks	3
4-1	Approach Profiles, graphic and tabular, Wunstorf, Germany	7
4-2	Approach Profiles, graphic and tabular, Vaerlose, Denmark	8
4-3	Approach Profiles, graphic and tabular, Mildenhall, England	9
4-4	Approach Profiles, graphic and tabular, Lorient, France	9
5-1	Comparison of reported visibilities and derived visual ranges	11

PRECEDING PAGE BLANK-NOT FILMED

SPRING AND FALL MEASUREMENTS OF EUROPEAN VERY LOW ALTITUDE VOLUME SCATTERING COEFFICIENTS

Richard W. Johnson

1. INTRODUCTION

In the increasingly sophisticated world of electro-optical detection, search, and guidance, the requirement for establishing and predicting atmospheric influences on system performance continues to develop as a primary operational necessity. It is in support of this general context that the Visibility Laboratory in cooperation with, and under the sponsorship of the Air Force Geophysics Laboratory has maintained an extensive program of airborne optical and meteorological measurements. In recent years this program has been conducted as an independent but cooperative effort [Johnson *et al.* (1979)] in conjunction with the NATO program OPAQUE (Optical Atmospheric Quantities in Europe), Fenn (1978). During the two year interval spanning the years 1977 and 1978, over 80 missions were flown documenting the vertical structure of the visible spectrum total volume scattering coefficient in the lower troposphere. Since a thorough awareness of this vertical structure is essential to the prediction of atmospheric influences on contrast transmittance through this regime, these data have been presented in a series of technical reports, the most recent of which is entitled "Airborne Measurements of Atmospheric Volume Scattering Coefficients in Northern Europe, Summer 1978", Johnson and Gordon (1980).

The optimum use of the experimental data presented in reports such as Johnson and Gordon (1980) is surely to establish the baseline assessment of those optical characteristics most influencing slant path contrast transmittance, and to develop from these assessments realistic predictive models. An initial effort in this model development, using both surface and profile data from the OPAQUE program is discussed in Johnson *et al.* (1979), and the further application of these data to contrast transmittance modelling is illustrated by Hering (1981).

As discussed briefly in the earlier issuance of this two report series, *i.e.* AFGL-TR-81-0154, Johnson (1981a), there has been a systematic gap in the data describing the vertical variations in low altitude atmospheric scattering coefficients, which has been particularly troublesome when addressing the performance of low flying electo-optical systems. The data contained in this Spring-Fall report in conjunction with the previously presented Winter-Summer data set are intended to reduce substantially the uncertainties in the structure of the near surface scattering coefficient profile.

An identification of the flight data included in this Spring-Fall report is provided in Table 1.1. As in the Winter-Summer set, these data represent measurements made following each experimental data flight during the instrumented aircraft's approach and landing sequences. The flights indicated in Table 1.1 are mostly from the OPAQUE I, II and III deployments, Duntley *et al.* (1977, 1978a and 1978b). For completeness, two flights made at Vaerlose, Denmark during the summer of 1978 have been included with the summer of 1977 data.

Table 1.1.

Flight Identification Data

Aerodrome Identification	Flight No.	Flight Date	Landing Time (GMT)
Wunstorf, Germany 52°28'N 09°25'E 57m MSL	381	25 May 76	14 28 03
	392	1 Nov 76	13 23 29
	393	2 Nov 76	11 50 35
	394	18 Nov 76	13 58 34
	396	22 Nov 76	11 05 50
	397	23 Nov 76	14 10 53
	414	28 Jul 77	11 59 28
	415	29 Jul 77	12 49 11
	416	1 Aug 77	15 36 51
	418	4 Aug 77	10 46 50
	419	4 Aug 77	16 47 35
Vaerlose, Denmark 55°46'N 12°20'E 18m MSL	378	12 May 76	11 48 54
	379	17 May 76	14 01 33
	391	26 Oct 76	13 27 37
	421	10 Aug 77	14 37 54
	422	11 Aug 77	11 57 48
	478	25 Sep 78	16 42 27
	479	26 Sep 78	13 16 47
Mildenhall, England 52°22'N 00°29'E 10m MSL	377	10 May 76	13 45 14
Lorient, France 47°46'N 03°33'W 52m MSL	398	2 Dec 76	14 45 37
	400	4 Dec 76	13 27 42
	401	5 Dec 76	14 51 04
	402	6 Dec 76	15 26 16
	410	4 Jul 77	15 04 52
	411	6 Jul 77	11 54 52

2. PROCEDURES & INSTRUMENTATION

The general flight sequences conducted during the OPAQUE measurement program have been reported in several preceding reports as noted in bottom row entries of Table 2.1. In these earlier reports, measurements of atmospheric volume scattering coefficient and natural irradiance levels were presented for a broad variety of geographical and seasonal conditions. The general locale for these data missions is illustrated in Fig. 2-1 which has been abstracted from Johnson *et al.* (1979). The aerodromes at which the approach data were measured are indicated by the symbol, ★, whereas the flight track locations for the previously reported data are indicated by short solid lines *e.g.* near Birkhof.

The instrumentation used during these flight episodes has been described adequately in the previously referenced reports [Johnson and Gordon (1980), etc.] and will not be further elaborated upon herein. Suffice it to say that the entire instrument system was mounted on an Air Force C-130 aircraft and included, but was not limited to, the following listed items:

a. A multi-channel, multi-spectral nephelometer for the measurement of atmospheric total volume scattering coefficient and directional scattering functions,

b. multi-spectral scanning radiometers for the measurement of sky and terrain radiances,

c. a multi-spectral, two channel flat plate irradiometer for the measurement of upwelling and downwelling irradiance levels, and

d. meteorological transducers for the measurement of ambient temperature, dewpoint temperature and atmospheric pressure.

As noted in Johnson (1981a), a special measurement sequence was associated with most flights discussed in these earlier reports, but its resultant data were not included as part of the standard flight package, nor included in those reports. These specialized data resulted from having the airborne optical, meteorological, and data logging instrumentation operational during the aircraft's landing approach and touchdown. Thus, since the aircraft was staging out of an airfield generally remote from the standard OPAQUE flight tracks shown in Fig. 2-1, two separate and independent data sets were collected during most missions. The first was the rather extensive, multispectral set of measurements made along the indicated tracks between 6.0 and 0.5 kilometers in altitude, and the second was the smaller more selective set made at the local staging base between about 0.7 and 0.0 kilometers. This second set of measurements, made only in the photopic spectral band, is nominally referred to as the APPROACH data, and is the subject of this report, the second in a two report series.

The general operating procedures employed during these APPROACH flight sequences were similar in nature to those described in each of the reports listed in Table 2.1. A few specific, but minor, variations in the procedure are discussed in the companion Winter-Summer report, Johnson (1981a).

Post deployment data processing of these data has been handled in a manner similar to that described in Johnson and Gordon (1979). Calibration data for each deployment set is the same as was used for the parent data sets as referenced in each of the Related Data Report entries of Table 2.1. Readers are referred to these more detailed reports for supplementary background information where required.

Table 2.1.

Geographical and Seasonal Distribution of
Low Altitude Scattering Coefficient Profiles

Aerodrome Locations (see Fig. 2-1)	Attempted Low Altitude Data Sequences				
	Spring, 1976	Fall, 1976	Summer 1977 & 1978	Winter 1978	Totals
Sigonella, Sicily (SIG)	0	0	4	4	8
Lorient, France (LOR)	0	4*	3*	0	7
Memmingen, Germany (MEM)	0	0	3	6	9
Wunstorf, Germany (WUN)	3*	5*	13*	4	25
Soesterberg, Netherlands	1	0	0	0	1
Mildenhall, England (MIL)	4*	0	3	6	13
Vaerlose, Denmark (VAR)	2*	1*	4*	0	7
Totals	10	10	30	20	70
Related Data Reports	AFGL-TR-77-0078	AFGL-TR-77-0239	AFGL-TR-78-0168 AFGL-TR-80-0207	AFGL-TR-79-0159	AFGL-TR-79-0285

*Asterisk indicates those sub-sets from which the data in this report were chosen.

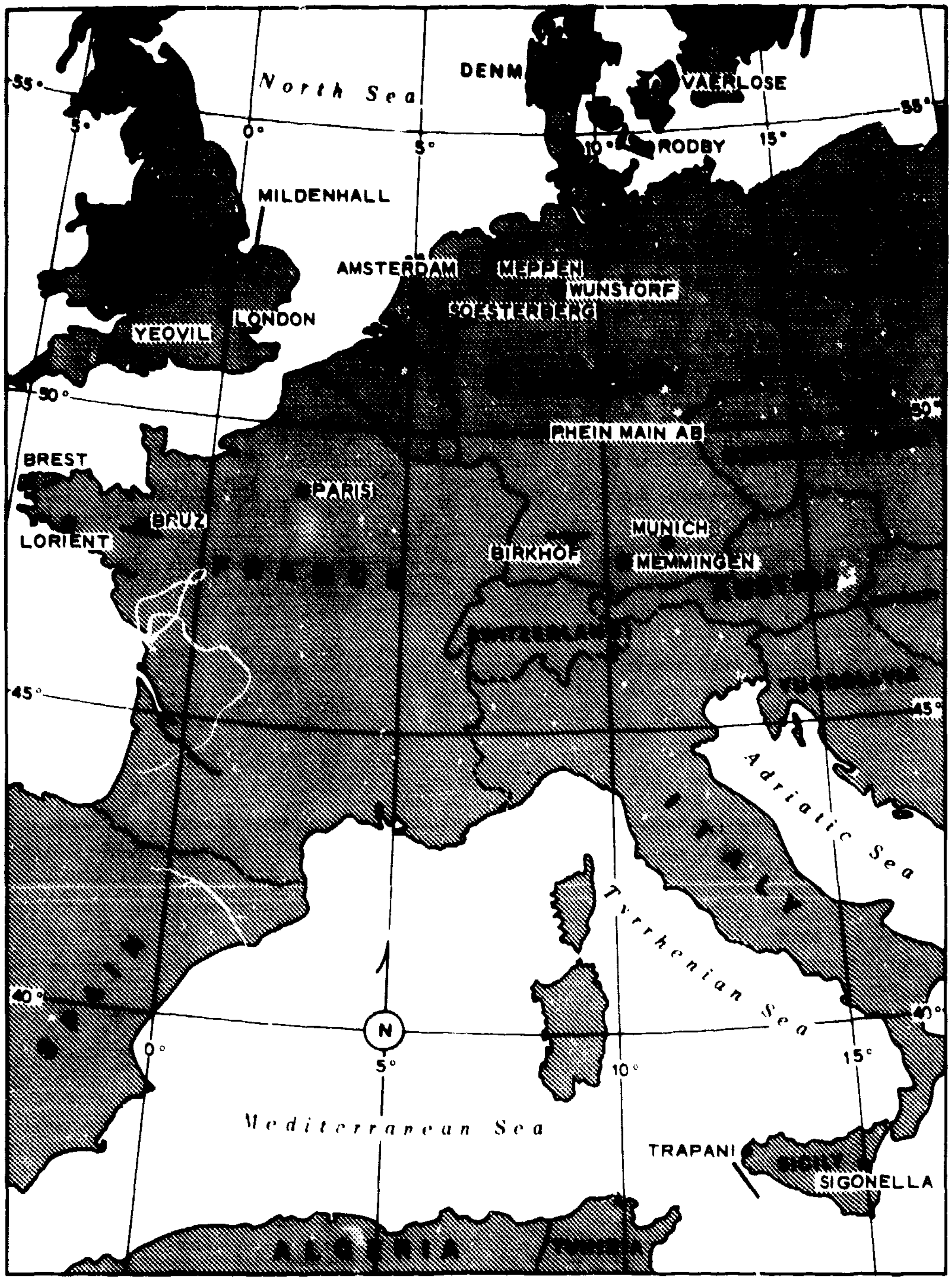


Fig. 2-1. Typical OPAQUE Flight Tracks.

3. WEATHER SUMMARY

The weather conditions existing during each of the flight episodes from which the APPROACH profiles have been extracted are discussed in detail in Johnson and Gordon, 1979 and 1980. These parent reports include data from daily surface and 500 millibar charts, surface observations, pilot reports, vertical cross sections and radiosonde launches. The bulk of these data were provided by the U.S. Air Force Environmental Technical Applications Center (USAFETAC) at Scott Air Force Base, and the National Oceanographic and Atmospheric Administration via the National Climatic Center in Asheville, North Carolina.

Comparisons between the C-130 and RAOB airborne measurements of temperature, dewpoint temperature, and the derived values of relative humidity for each of the flights preceding these APPROACH episodes have been made in the parent reports referenced above. However, several additional comparisons are summarized herein which relate more directly to the actual landing circumstances.

Measured values of temperature (t), dewpoint temperature (dp), and atmospheric pressure (p), that were recorded at the exact moment of landing touchdown have been compared with the equivalent values reported by the host aerodrome for fifteen of the flights reported in Section 4. These flights were those for which the flight dynamics data permitted a specific and unambiguous determination of the exact instant of landing. Those flights for which the landing time was for any reason nonspecific were not included in the comparison, even though their data might in fact be suitable in all other respects. These comparisons are listed in Table 3.1. In all cases the differences, Δt, Δdp and Δp, represent the aerodrome measurement minus the C-130 measurement.

The data summarized in Table 3.1 indicate that the airborne and aerodrome measurements were on the average in reasonable agreement, although not as closely related as were the measurements during OPAQUE IV & V (Johnson, 1981a). The temperature data indicate a systematic difference of about 1°C between the C-130 and aerodrome measurements. The dewpoint and pressure measurements indicate substantially larger offsets.

There was an instrumentation failure in the dewpoint hygrometer system during flight C-399 (6 Dec 1976) that may have influenced the data during the immediately preceeding OPAQUE II missions. Intermittent evidences of system failure were first noticed in the flight C-395 (19 Nov 1976) data, and were deleted during post-mission processing (Duntley *et al.*, 1977). However, a residual artifact of this system failure, and its subsequent repair may be evidenced in the data of Table 3.1. In an examination of the dewpoint differences, one notes that the differences associated with the OPAQUE I and II deployments, (flights 370 through 402) are all negative in sign and mostly small in magnitude. In contrast, the differences associated with the OPAQUE III deployment (flights 410 through 422) are all positive in sign and generally larger in magnitude. One may compare the data in Table 3.1 with the equivalent data presented previously in the companion Winter-Summer report, AFGL-TR-81-0154. In this comparison it appears that the

Table 3.1

Comparison of Aerodrome & C-130 Data Differences (Measurements During Landing)

Aerodrome	Flight Number	Temperature Δt (°C)	Dew Point Δdp (°C)	Pressure Δp (mb)
Wunstorf	381	+0.6	-2.1	-1
	393	+1.5	-0.2	-3
	397	+0.8	-1.0	-4
	414	+1.4	+5.7	-4
	415	-1.5	+2.5	-4
	416	+2.3	+5.0	-5
	418	+1.4	+6.7	-7
	419	+1.8	+6.0	-5
Vaerloese	378	-0.9	-1.2	-4
	379	+0.1	-5.2	-6
	421	+0.8	+4.8	-5
	422	+0.6	+4.9	-10
Lorient	402	+0.8	MSG	-5
	410	+1.4	+1.4	-10
Mildenhall	377	+3.5	-1.5	1
Overall Average	15 flights	+1.0	OPQ I&II (7) -1.9; OPQ III (8) +4.6	-4.9

1. Δt is positive 14/16 cases, implying same systematic offset as also seen in the Winter-Summer data (Johnson, 1981a)

2. Δp is negative in all cases implying systematic offset and larger than Winter-Summer data.

3. Δdp is all neg. for OPQ I & II, but all pos for OPQ III Winter-Summer data: small and variable

measured differences, Δdp, are similar in sign and magnitude for the OPAQUE I, II, IV and V data, while the differences for the OPAQUE III set are systematically positive and large. There is no evidence of malfunction or calibration error associated with the dewpoint system during the OPAQUE III interval, so at this time the apparently anomalous behavior is unexplained.

Since the staging aerodromes for most of these flights were generally remote from the primary data tracks, selected supplemental weather data related specifically to the APPROACH site have been included herein. Short summaries of the meteorological observations taken at the staging aerodrome, at or near the time of landing are presented in Table 3.2. A glossary of the most often used symbols is included in Appendix A for the reader's convenience. All data were reported in Greenwich Civil Time (GCT), which is equivalent to Greenwich Mean Time (GMT), the terminology used in Table 3.2.

Table 3.2a Wunstorf, Germany Standard Meteorological Data Sheet Lat. 52°28'N Long. 09°25'E El. 57m

Spring 1976

Time GMT	Cloud Cover	Visibility (Kilometers)	Weather and Obstructions To Vision	Temp. (°C)	Dewpoint (°C)	Wind Direction (00-36)	Wind Speed (mps)	Remarks
Flight No. C-381	**Date: 25 May 1976**							
1344	Cloud Data Unknown	11.2		14.0	7.0	-	1.0	Ceiling 5000 Feet

Table 3.2a (Con't.) Wunstorf, Germany

Fall 1976

Flight No. C-393	**Date: 2 November 1976**							
1144	200⦶	11.2		13.0	7.0	22	6.6	
1244	200⦶	11.2		13.0	6.0	24	6.6	
Flight No. C-394	**Date: 18 November 1976**							
1444	E40⊕	1.7	F-	5.0	2.0	07	2.5	Sky Overcast Type Missing
Flight No. C-396	**Date: 22 November 1976**							
1144	Cloud Data Unknown	11.2	RW-	5.0	0.0	29	6.6	
Flight No. C-397	**Date: 23 November 1976**							
1444	Cloud Data Unknown	11.2		2.0	0.0	28	6.6	Ceiling 2500 Feet Rain Shower During Past Hour

Summer 1977

Flight No. C-414	**Date: 28 July 1977**							
1144	Cloud Data Unknown	11.2		19.2	11.2	33	1.0	Ceiling 8000 Feet
Flight No. C-415	**Date: 29 July 1977**							
1244	Cloud Data Unknown	11.2		19.2	11.2	u	1.0	Ceiling 27000 Feet
Flight No. C-416	**Date: 1 August 1977**							
1644	Cloud Data Unknown	11.2		19.2	13.2	31	6.1	Ceiling Unlimited
Flight No. C-418	**Date: 4 August 1977**							
1044	Cloud Data Unknown	6.0	H	21.2	16.2	30	3.6	Ceiling Unlimited
Flight No. C-419	**Date: 4 August 1977**							
1644	Cloud Data Unknown	4.9	H	23.2	16.2	03	0.5	Ceiling Unlimited

Table 3.2b Vaerlose, Denmark Standard Meteorological Data Sheet Lat. 55°46'N Long. 12°20'E El. 18m

Spring 1976

Time GMT	Cloud Cover	Visibility (Kilometers)	Weather and Obstructions To Vision	Temp. (°C)	Dewpoint (°C)	Wind Direction (00-36)	Wind Speed (mps)	Remarks
Flight No. C-378	**Date: 12 May 1976**							
1200	25⦶u-⦶/⦶	40.0		13.0	5.0	16	7.2	
Flight No. C-379	**Date: 17 May 1976**							
1250	Cloud Data Unknown	11.2		16.0	5.0	12	2.5	1/8 Cover
1320	Cloud Data Unknown	11.2		17.0	4.0	09	1.5	1/8 Cover
			Fall 1976					
Flight No. C-391	**Date: 26 October 1976**							
1420	E19⦶	7.0	F-			08	5.6	
			Summer 1977					
Flight No. C-421	**Date: 10 August 1977**							
1420	Cloud Data Unknown	11.2		21.2	14.2	15	4.1	Ceiling Unlimited
1450	Cloud Data Unknown	8.0	H	20.2	15.2	17	4.6	Ceiling Unlimited
Flight No. C-422	**Date: 11 August 1977**							
1150	Cloud Data Unknown	8.0	R-	19.2	16.2	01	2.5	Ceiling 8000 Feet
1200	Cloud Data Unknown	8.0	R-	19.2	16.2	01	2.1	Ceiling 8000 Feet
			Summer 1978					
Flight No. C-478	**Date: 25 September 1978**							
1650	Cloud Data Unknown	11.2	R-	13.2	8.2	24	7.2	Ceiling 8000 Feet
1750	Cloud Data Unknown	11.2		11.2	8.[illegible]	25	6.6	Ceiling Unlimited
Flight No. C-479	**Date: 26 September 1978**							
1250	Cloud Data Unknown	11.2		14.2	8.2	24	7.3	Ceiling 7000 Feet
1350	Cloud Data Unknown	11.2		14.2	8.2	23	7.2	Ceiling 9000 Feet

Table 3.2c Mildenhall, England Standard Meteorological Data Sheet Lat. 52°22'N Long. 00°29'E El. 10m

Spring 1976

Time GMT	Cloud Cover	Visibility (Kilometers)	Weather and Obstructions To Vision	Temp. (°C)	Dewpoint (°C)	Wind Direction (00-36)	Wind Speed (mps)	Remarks
Flight No. C-377 Date: 10 May 1976								
1400	Cloud Data Unknown	6.0	H	18.0	11.0	33	6.6	Ceiling 2300 Feet

Table 3.2d Lorient, France Standard Meteorological Data Sheet Lat. 47°46'N Long. 03°33'E El. 52m

Fall 1976

Time GMT	Cloud Cover	Visibility (Kilometers)	Weather and Obstructions To Vision	Temp. (°C)	Dewpoint (°C)	Wind Direction (00-36)	Wind Speed (mps)	Remarks
Flight No. C-398 Date: 2 December 1976								
1500	Cloud Data Unknown	8.0	RW-	8.0	6.0	32	6.6	
Flight No. C-400 Date: 4 December 1976								
1400	15⦶u-⦶ E230⦷	11.2		7.0	3.0	30	4.1	
1500	15⦶u-⦶ E230⦷	10.0		6.0	4.0	28	2.6	
Flight No. C-401 Date: 5 December 1976								
1400		11.2		9.0	4.0	22	3.6	
1500	25⦶u-⦶/⦶	20.0		9.0	3.0	24	3.1	
Flight No. C-402 Date: 6 December 1976								
1500	Cloud Data Unknown	10.0		11.0	8.0	24	12.4	
1600	Cloud Data Unknown	11.2				24	13.3+	Gusts to 20.55
			Summer 1977					
Flight No. C-410 Date: 4 July 1977								
1500	35⦶120⦶/⦷	5.0	TRW-	21.2	19.2	24	3.1	
Flight No. C-411 Date: 6 July 1977								
1200	35⦶120⦶/⦶	5.0		26.2	19.2	06	3.6	

4. DATA PRESENTATION

4.1 Data and Flight Summary

During the Spring of 1976 (2 April through 26 May), thirteen flights were made in northern Europe, of which eight contained useable profile data. These data were reported in Duntley *et al.* (1977). Of these thirteen, four contained recoverable approach profiles. These four are listed in Table 1.1.

During the following fall (25 October through 6 December) thirteen additional flights were made in the same general areas, of which twelve contained useable profile data. These data were reported in Duntley *et al.* (1978a). Of these thirteen, ten contained recoverable approach data. These ten are also listed in Table 1.1.

During the following Summer of 1977 (4 July through 11 August) another thirteen flights were accomplished and subsequently reported in Duntley *et al.* (1978b). From this third set of flights, an additional nine contained recoverable approach data. These nine are listed in Table 1.1 as are two additional flights from the Summer of 1978 deployment (flights 478 & 479, 25 and 26 Sep 1978).

4.2 Description of Data Tables and Graphs

The flight data for the APPROACH sequences listed in Table 1.1 are presented both tabularly and graphically in Figs. 4-1, 4-2 and 4-3. The spring, fall and summer measurements at each of four aerodromes appear grouped by location for ease of comparison.

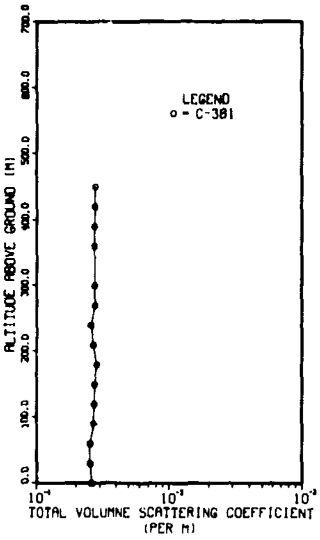
The scattering coefficient profiles represent measurements made continuously during each final descent which have been averaged vertically to yield one data point every 30 meters in altitude. The measurements were all made using a pseudo-photopic spectral response having a mean wavelength of 557 nm. Altitudes are reported in meters above ground level (AGL).

4.3 Supplementary Data Entries

In the tabular displays, four additional entries have been included as peripheral information. The first is the local visibility reported by the station meteorologist and abstracted from Table 3.2. The second is the ground level scattering coefficient (s), as measured by the C-130 nephelometer, converted to approximate visual range (VR) via the expression

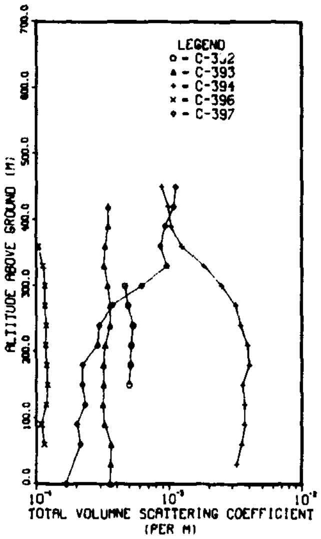
$$VR \approx 3/s$$

as discussed by Douglas and Young (1945), Middleton (1952) and Gordon (1979). A comparison was anticipated between these measured values and the visual estimates made by the aerodrome meteorological observer, however for eleven of the twenty-six landing intervals, the meteorological report was truncated at 11.2 km (7 statute



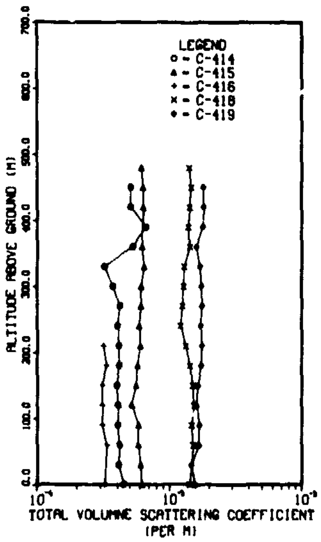
WUNSTORF, GERMANY SPRING 1976

Altitude (m) AGL	Total Volume Scattering Coefficient (m^{-1})				
	C381				
450	2.762E-04				
420	2.752E-04				
390	2.721E-04				
360	2.728E-04				
330	2.737E-04				
300	2.746E-04				
270	2.744E-04				
240	2.571E-04				
210	2.658E-04				
180	2.837E-04				
150	2.715E-04				
120	2.713E-04				
90	2.687E-04				
60	2.525E-04				
30	2.533E-04				
0	2.600E-04				
Reported Visibility (km)	≥11.2				
Visual Range (km)	11.5				
Illumination (lux)	55400				
Landing Time (GMT)	1428				



WUNSTORF, GERMANY FALL 1976

Altitude (m) AGL	Total Volume Scattering Coefficient (m^{-1})				
	C392	C393	C394	C396	C397
450			8.782E-04		1.120E-03
420		3.443E-04	9.862E-04		1.088E-03
390		3.459E-04	1.042E-03		9.347E-04
360		3.258E-04	1.244E-03	1.025E-04	8.595E-04
330		3.199E-04	1.847E-03	1.114E-04	9.665E-04
300	4.639E-04	3.394E-04	2.509E-03	1.147E-04	6.203E-04
270	4.927E-04	3.583E-04	3.225E-03	1.154E-04	3.734E-04
240	5.351E-04	3.545E-04	3.472E-03	1.175E-04	2.937E-04
210	5.230E-04	3.270E-04	3.914E-03	1.169E-04	2.87[illegible]E-04
180	5.131E-04	3.162E-04	4.001E-03	1.182E-04	2.226E-04
150	5.026E-04	3.193E-04	3.598E-03	1.210E-04	2.224E-04
120		3.128E-04	3.716E-03	1.176E-04	2.325E-04
90		3.216E-04	3.721E-03	1.083E-04	2.023E-04
60		3.597E-04	3.524E-03	1.135E-04	2.147E-04
30		3.585E-04	3.260E-03		1.911E-04
0		3.555E-04			1.674E-04
Reported Visibility (km)	MSG	≥11.2	1.7	≥11.2	≥11.2
Visual Range (km)	6.0	8.3	9.1	26.5	18.0
Illumination (lux)	23500	32000	3100	11000	2300
Landing Time (GMT)	1323	1150	1358	1105	1410

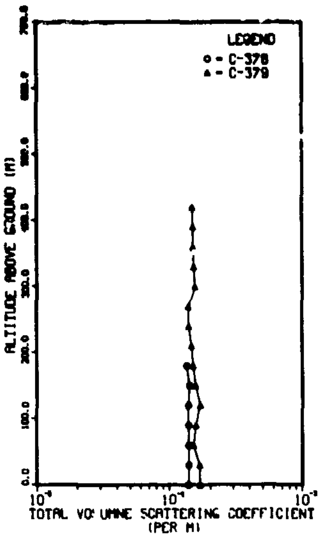


WUNSTORF, GERMANY SUMMER 1976

Altitude (m) AGL	Total Volume Scattering Coefficient (m^{-1})				
	C414	C415	C416	C418	C419
480		6.105E-04		1.397E-03	
450	5.065E-04	6.333E-04		1.452E-03	1.794E-03
420	5.105E-04	6.380E-04		1.421E-03	1.816E-03
390	6.640E-04	6.275E-04		1.385E-03	1.777E-03
360	5.250E-04	6.170E-04		1.414E-03	1.581E-03
330	3.186E-04	6.426E-04		1.289E-03	[illegible].695E-03
300	3.696E-04	6.122E-04		1.281E-03	1.743E-03
270	4.167E-04	6.080E-04		1.247E-03	1.747E-03
240	3.999E-04	5.928E-04		1.213E-03	1.716E-03
210	4.082E-04	6.001E-04	3.139E-04	1.321E-03	1.744E-03
180	4.136E-04	5.736E-04	3.321E-04	1.429E-03	1.729E-03
150	3.930E-04	5.566E-04	3.072E-04	1.486E-03	1.632E-03
120	4.037E-04	5.143E-04	3.095E-04	[illegible].527E-03	1.590E-03
90	4.004E-04	5.798E-04	3.074E-04	1.456E-03	1.668E-03
60	4.130E-04	5.771E-04	3.308E-04	1.497E-03	1.651E-03
30	4.066E-04	6.033E-04	3.266E-04	1.460E-03	1.449E-03
0	4.480E-04	6.196E-04	3.223E-04	1.422E-03	1.569E-03
Reported Visibility (km)	≥11.2	≥11.2	≥11.2	6.0	4.9
Visual Range (km)	6.7	4.8	9.4	2.1	1.9
Illumination (lux)	49300	58800	34200	53600	22000
Landing Time (GMT)	1159	1249	1536	1046	1647

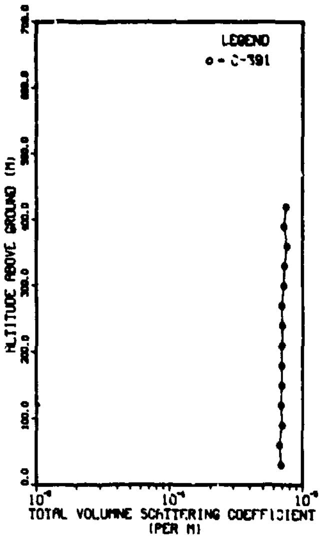
Graphic **Tabular**

Fig. 4-1. APPROACH Profiles - Wunstorf, Germany.



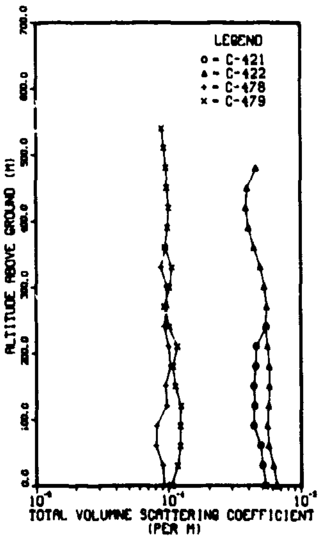
VAERLOSE, DENMARK SPRING 1976

Altitude (m) AGL	Total Volume Scattering Coefficient (m^{-1})				
	C378	C379			
420.		1.495E-04			
390.		1.509E-04			
360.		1.501E-04			
330.		1.520E-04			
300.		1.546E-04			
270.		1.393E-04			
240.		1.406E-04			
210.		1.465E-04			
180.	1.353E-04	1.510E-04			
150.	1.412E-04	1.571E-04			
120.	1.387E-04	1.700E-04			
90.	1.402E-04	1.587E-04			
60.	1.396E-04	1.512E-04			
30.	1.398E-04	1.680E-04			
0.	1.390E-04	1.690E-04			
Reported Visibility (km)	40.0	≥11.2			
Visual Range (km)	21.6	17.8			
Illumination (lux)	70100	51000			
Landing Time (GMT)	1148	1401			



VAERLOSE, DENMARK FALL 1976

Altitude (m) AGL	Total Volume Scattering Coefficient (m^{-1})				
	C391				
420.	7.480E-04				
390.	7.159E-04				
360.	7.625E-04				
330.	7.267E-04				
300	7.181E-04				
270.	6.910E-04				
240.	6.982E-04				
210.	6.940E-04				
180.	6.937E-04				
150.	6.912E-04				
120.	6.829E-04				
90.	6.958E-04				
60.	6.708E-04				
30.	6.851E-04				
0.					
Reported Visibility (km)	7.0				
Visual Range (km)	4.3				
Illumination (lux)	6200				
Landing Time (GMT)	1327				



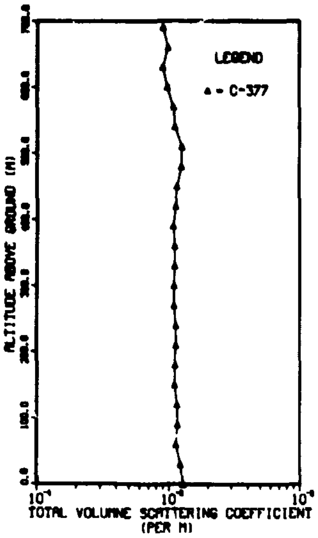
VAERLOSE, DENMARK SUMMER 1977 & 1978

Altitude (m) AGL	Total Volume Scattering Coefficient (m^{-1})				
	C421	C422		C478	C479
540.					8.919E-05
510.					9.235E-05
480.		4.530E-04			9.525E-05
450.		3.937E-04			9.738E-05
420.		3.848E-04			1.002E-04
390.		4.017E-04			9.823E-05
360.		4.390E-04		9.491E-05	9.373E-05
330.		4.864E-04		8.738E-05	1.049E-04
300.		5.240E-04		9.683E-05	1.017E-04
270.		5.468E-04		9.737E-05	9.347E-05
240	5.432E-04	5.322E-04		9.300E-05	1.009E-04
210.	4.569E-04	5.535E-04		9.983E-05	1.159E-04
180	4.517E-04	5.670E-04		1.028E-04	1.067E-04
150.	4.355E-04	5.686E-04		9.400E-05	1.114E-04
120.	4.416E-04	5.615E-04		9.638E-05	1.224E-04
90.	4.376E-04	5.549E-04		8.177E-05	1.218E-04
60	4.908E-04	5.654E-04		8.062E-05	1.217E-04
30.	5.073E-04	6.148E-04		9.052E-05	1.158E-04
0.	5.350E-04	6.526E-04		9.193E-05	1.042E-04
Reported Visibility (km)	8.0	8.0		≥11.2	≥11.2
Visual Range (km)	5.6	4.6		32.6	28.8
Illumination (lux)	34400	17700		1300	21000
Landing Time (GMT)	1437	1157		1642	1316

Graphic

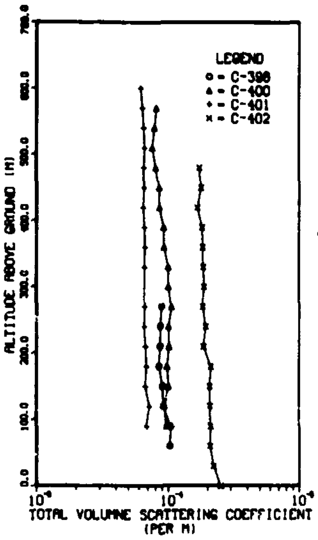
Tabular

Fig. 4-2. APPROACH Profiles - Vaerlose, Denmark.



MILDENHALL, ENGLAND SPRING 1976

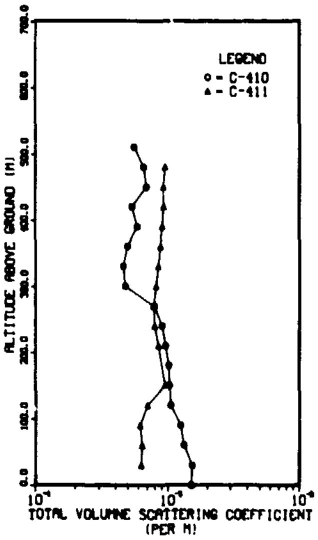
Altitude (m) AGL	Total Volume Scattering Coefficient (m^{-1})				
	C377				
690.	8.893E-04				
660	9.693E-04				
630	8.874E-04				
600	9.605E-04				
570.	1.068E-03				
540.	1.094E-03				
510	1.239E-03				
480.	1.232E-03				
450	1.141E-03				
420	1.110E-03				
390	1.069E-03				
360.	1.097E-03				
330.	1.095E-03				
300.	1.088E-03				
270.	1.088E-03				
240.	1.136E-03				
210.	1.127E-03				
180.	1.132E-03				
150	1.096E-03				
120	1.147E-03				
90.	1.160E-03				
60.	1.130E-03				
30.	1.228E-03				
0.	1.272E-03				
Reported Visibility (km)	6.0				
Visual Range (km)	2.4				
Illumination (lux)	12000				
Landing Time (GMT)	1345				



*Note Scale Change

LORIENT, FRANCE FALL 1976

Altitude (m) AGL	Total Volume Scattering Coefficient (m^{-1})				
	C398	C400	C401	C402	
600			6.149E-05		
570		8.091E-05	6.342E-05		
540		7.839E-05	6.489E-05		
510		7.543E-05	6.610E-05		
480		8.013E-05	6.528E-05	1.718E-04	
450		8.474E-05	6.516E-05	1.759E-04	
420		8.518E-05	6.419E-05	1.645E-04	
390		9.175E-05	6.563E-05	1.801E-04	
360		9.242E-05	6.648E-05	1.820E-04	
330		9.933E-05	6.600E-05	1.840E-04	
300		1.000E-04	6.593E-05	1.876E-04	
270	8.839E-05	1.047E-04	6.585E-05	1.813E-04	
240	8.656E-05	9.957E-05	6.522E-05	1.919E-04	
210	8.636E-05	1.005E-04	6.678E-05	1.839E-04	
180	8.470E-05	9.744E-05	6.827E-05	2.106E-04	
150	9.019E-05	1.001E-04	6.686E-05	2.064E-04	
120	9.157E-05	9.356E-05	7.173E-05	2.078E-04	
90	1.035E-04	9.611E-05	6.822E-05	2.096E-04	
60	1.020E-04			2.074E-04	
30				2.218E-04	
0				2.517E-04	
Reported Visibility (km)	8.0	≥11.2	≥11.2	10	
Visual Range (km)	29.4	31.2	44.1	12.0	
Illumination (lux)	2300	30900	11200	1500	
Landing Time (GMT)	1445	137'	1451	1526	



LORIENT, FRANCE SUMMER 1976

Altitude (m) AGL	Total Volume Scattering Coefficient (m^{-1})				
	C410	C411			
510	5.561E-04				
480	6.541E-04	9.503E-04			
450	6.883E-04	9.252E-04			
420	5.370E-04	9.280E-04			
390	5.899E-04	9.059E-04			
360	4.923E-04	8.743E-04			
330	4.586E-04	8.402E-04			
300	4.753E-04	8.115E-04			
270	7.857E-04	7.776E-04			
240	9.024E-04	7.921E-04			
210	9.583E-04	8.469E-04			
180	1.015E-03	8.995E-04			
150	1.026E-03	9.521E-04			
120	1.038E-03	6.996E-04			
90	1.236E-03	6.194E-04			
60	1.317E-03	6.401E-04			
30	1.521E-03	6.263E-04			
0	1.497E-03				
Reported Visibility (km)	5.0	5.0			
Visual Range (km)	2.0	4.8			
Illumination (lux)	4600	67000			
Landing Time (GMT)	1504	1154			

Graphic | Tabular

Fig. 4-3. APPROACH Profiles - Mildenhall, England & Lorient, France.

miles) *i.e.* VV>11.2 km was reported as 11.2 km. This common aeronautical practice precluded the accumulation of as large a comparative data base as was desired, however there are seventeen instances of reasonable simultaneity that may be representative of the overall comparison listed in Table 5.2. The reported visual estimates are also included in the supplementary data for the reader's convenience.

The third peripheral item is the measurement of total downwelling illumination at the time of landing. These measurements, also made in the pseudo-photopic spectral band, are reported in units of *lux* (*lumens*/m^2) and can be compared directly with standard tables of natural illumination such as Brown (1952) by utilizing the location and time information listed in Table 1.1. These specific comparisons however, have not been included in this report.

The final supplementary entry is the time of landing touchdown. These times, indicated in GMT, have been extracted from Table 1.1 and truncated to hours and minutes only.

5. DATA DISCUSSION

As noted in the introductory remarks of section 1 in both this report and it's Winter-Summer companion, Johnson, 1981a, the accurate specification of the atmospheric volume scattering characteristics at very low altitudes can be critical to the determination of slant path contrast transmittances through this near surface regime. It is of major importance for one to know, or be able to reliably deduce, the occurrence of major variations in the vertical structure of the atmospheric aerosol. The flight data represented in the earlier referenced reports, Johnson and Gordon, 1980 etc., have provided extensive samples of these variations and thus have served as the case studies required for developing reasonable modelling representations. A preliminary discussion of a proposed modelling technique was originally discussed in Johnson *et al.* 1979, has been amplified upon in Johnson and Hering, 1981, and is described further in Hering, 1981.

Since the profile data upon which the Hering model was developed terminated at 500 to 1000 ft. (150-300m) above the ground, the confidence with which one could specify the low level scattering properties from these data was somewhat compromised. The data presented in section 4 of this current report, in addition to that presented in Johnson, 1981a, specifically address the resolution of the uncertainty in this specification. They support the contention that in most cases, midday measurements of atmospheric volume scattering coefficient made within the 150-300m AGL altitude regime may be reliably extrapolated down to the surface with only marginal risk of significant error within the context of overall model performance. Of the twenty-five scattering coefficient profiles illustrated in Section 4, only four, two in the Fall and two in the Summer seasons show marked structure within the low level haze. Thus, as summarized in Table 5.1, there are only seven flights out of the total fifty-one reported in these two companion reports which illustrate clearly discernible variations in the magnitude of the near surface haze profile.

There were twelve instances within the twenty-five landing episodes where the station visibility was reported as less than 11.2 km and therefore could be approximated by the derived value of visual range (VR = 3/s) as discussed in Section 3. These twelve values plus the five available from the companion Winter-Summer report are summarized in Table 5.2 and illustrated in Fig. 5-1. The data points for two flights 378/VAR and 398/LOR have been omitted from the graphical display since they are substantially beyond the scale of the plot at visual ranges greater than 20 km. Whereas one might expect better comparisons between these pseudo-simultaneous determinations, there are good and sufficient reasons to anticipate a fair degree of spread within this small uncontrolled sample. Johnson (1981b). The trend in the comparison is reasonable for the most part, although the data tend to illustrate clearer derived values than those reported by station observers.

As an artifact of the site-season mix within the overall data set, only the Wunstorf site has a substantial

Table 5.1.

Summary of Conditions for Flights Profiles Illustrating Low Altitude Haze Structure

FLT NO/STA	Season	Surface Scat Coef (m^{-1})	Haze Top Altitude (m AGL)	Wind Direction-Speed (deg) · $msec^{-1}$	Obstructions to Vision	Dewpoint Depression STA (°C)	Dewpoint Depression C-130 (°C)
435/MEM	Winter	2.6 E-4	100	180 - 3.6	-	6	8.1
436/MEM	Winter	3.8 E-4	150	060 - 2.5	-	8	6.2
439/MEM	Winter	6.4 E-4	100	030 - 1.5	H	5	7.2
394/WUN	Fall	3.3 E-3	350	070 - 2.5	F-	3	0.7**
397/WUN*	Fall	1.7 E-4	350	280 - 6.6	RW	2	0.2**
410/LOR	Summer	1.5 E-3	300	240 - 3.1	TRW-	2	2.0
411/LOR*	Summer	6.3 E-4	1[illegible]	060 - 3.6	-	7	7.9

* Haziness increasing with increasing altitude.

** CAM-137 Dewpoint Hygrometer failed during the OPAQUE II deployment, and examination of the dewpoint temperature measurements indicates the high probability of an amplifier offset equivalent to approximately 2°C during the interval preceding the failure. These indicated dewpoint depressions therefore may be too small.

Table 5.2.

Comparison of Station Reported Visibilities and Nephelometer Derived Visual Ranges

FLT NO/STA	Season	Reported Visibility (km)	Derived Visual Range (km)
394/WUN	Fall '76	1.7	0.9
418/WUN	Summer '77	6.0	2.1
419/WUN	Summer '77	4.9	1.9
456/WUN	Winter '78	2.5	2
378/VAR	Fall '76	40	21.6
391/VAR	Fall '76	7.0	4.3
421/VAR	Summer '77	8.0	5.6
422/VAR	Summer '77	8.0	4.6
398/LOR	Fall '76	8.0	29.4
402/LOR	Fall '76	10	12.0
410/LOR	Summer '77	5.0	2.0
411/LOR	Summer '77	5.0	4.8
460/SIG	Summer '78	5	12
461/SIG	Summer '78	8	13
377/MIL	Spring '76	6.0	2.4
475/MIL	Summer '78	11	13
439/MEM	Winter '78	5	5

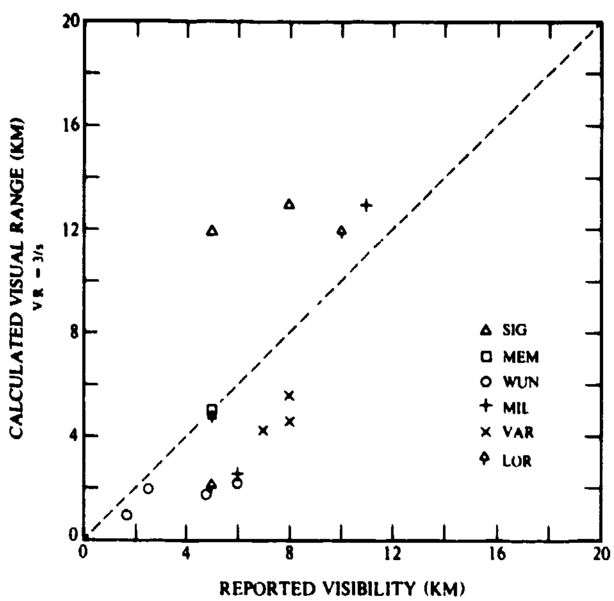


Fig. 5-1. Comparison of reported visibilities and derived visual ranges.

number of profiles appearing in both of these two companion reports. Thus, an enlarged comment upon the possibility of a higher seasonal variation in scattering coefficient existing during the Winter, as indicated in the Winter-Summer report, is probably not justified. Within the composite nineteen flight Wunstorf set; 4 Winter, 1978, 4 Summer 1978, 6 Spring and Fall 1976, and 5 Summer 1977; there does not seem to be any significant difference in the degree of scattering coefficient variation as a function of season. There is however a broad spread in the range of values encountered, as one might well expect, and in all but two of these nineteen instances, the profiles are remarkably constant within this near surface regime. As noted in the previous Winter-Summer report, these data by and large represent midday measurements and thus are based in favor of good convective mixing induced by solar heating of the ground surface.

5.1 Summary

Twenty-five vertical profiles of the photopic atmospheric volume scattering coefficient representing Spring, Fall and Summer conditions at four separate European aerodromes have been presented for evaluation. The basic question to be addressed is whether or not the scattering coefficient profile remains reasonably constant as one approaches the surface from an altitude of several hundred meters, and if not, what is the character of the vertical structure. These data indicate that in twenty-one out of twenty-five instances, the profile is essentially constant in value and thus the modelling approach proposed by Hering (1981) is in fact an appropriate procedure.

When combined with the data from the companion Winter-Summer data set, Johnson (1981a), forty-seven out of fifty-four (87%) of the profiles are represented by stable, nearly constant values of scattering coefficient within this very low altitude regime.

The identification of the conditions resulting in the seven profiles showing variations within their vertical structure will require additional analysis. A supplementary set of precision local meteorological observations including local trajectories would be beneficial.

6. ACKNOWLEDGEMENTS

This report has been prepared for the Air Force Geophysics Laboratory under Contract No. F19628-78-C-0200. The author wishes to thank the members of the Visibility Laboratory technical staff for their assistance in preparing these data, and in particular to acknowledge the contributions of Mr. Nils R. Persson, our senior computer specialist, and Ms. Alicia G. Hill and Mr. John C. Brown our specialists in computer assisted document preparation.

7. REFERENCES

Brown, D. R. E. (1952), *Natural Illumination Charts*, Report 374-1, Project Ns-714-100, Department of the Navy, Bureau of Ships, Washington, D.C.

Douglas, C. A. and L. L. Young (1945), "Development of Transmissometer for Determining Visual Range", U.S. Department of Commerce, Civil Aeronautics Administration, Washington, D.C., Technical Development Report No. 47.

Duntley, S. Q., R. W. Johnson, and J. I. Gordon (1977), "Airborne Measurements of Atmospheric Volume Scattering Coefficients in Northern Europe, Spring 1976," University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 77-8, AFGL-TR-77-0078.

Duntley, S. Q., R. W. Johnson, and J. I. Gordon (1978a), "Airborne Measurements of Atmospheric Volume Scattering Coefficients in Northern Europe, Fall 1976," University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 78-3, AFGL-TR-77-0239.

Duntley, S. Q., R. W. Johnson, and J. I. Gordon (1978b), "Airborne Measurements of Atmospheric Volume Scattering Coefficients in Northern Europe, Summer 1977", University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 78-28, AFGL-TR-78-0168.

Fenn, R. W. (1978), "OPAQUE - A Measurement Program on Optical Atmospheric Quantities in Europe, Vol. I The NATO OPAQUE Program", Special Reports No. 211, AFGL-TR-78-0011.

Gordon, J. I. (1979), "Daytime Visibility, a Conceptual Review", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 80-1, AFGL-TR-79-0257.

Hering, W. S. (1981), "An Assessment of Operational Techniques for Estimating Visible Spectrum Contrast Transmittance", Paper presented at the 25th Annual Technical Symposium of the Society of Photo-Optical Instrumentation Engineers, Seminar on Atmospheric Effects on Electro-Optical, Infrared and Millimeter Wave System Performance, San Diego California. (Aug. 1981)

Johnson, R. W. and W. S. Hering (1981), "Measurements of Optical Atmospheric Quantities in Europe and Their Application to Modelling Visible Spectrum Contrast Transmittance", Paper presented at the 29th Symposium of the AGARD Electromagnetic Wave Propagation Panel on Special Topics in Optical Propagation, Monterey, California. (April, 1981)

Johnson, R. W., W. S. Hering, J. I. Gordon, B. W. Fitch and J. E. Shields (1979), "Preliminary Analysis and Modelling Based Upon Project OPAQUE Profile and Surface Data", University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 80-5, AFGL-TR-79-0285.

Johnson, R. W. and J. I. Gordon (1979), "Airborne Measurements of Atmospheric Volume Scattering Coefficients in Northern Europe, Winter 1978", University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 79-25, AFGL-TR-79-0159.

Johnson, R. W. and J. I. Gordon (1980), "Airborne Measurements of Atmospheric Volume Scattering Coefficients in Northern Europe, Summer 1978", University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 80-20, AFGL-TR-80-0207.

Johnson, R. W. (1981a), "Winter and Summer Measurements of European Very Low Altitude Volume Scattering Coefficients", University of California, San Diego, Scripps Institution of Oceanography, SIO Ref. 80-00, AFGL-TR-81-0154.

Johnson, R. W. (1981b), "Daytime Visibility and Nephelometer Measurements Related to its Determination", ATMOSPHERIC ENVIRONMENT, 15, 10/11, 1835.

Middleton, W. E. K. (1952), *Vision Through the Atmosphere,* Chapter 10, University of Toronto Press.

METEOROLOGICAL GLOSSARY AND ABBREVIATIONS

SKY AND CEILING

Sky cover symbols are in ascending order. Figures preceding symbols are heights in hundreds of feet above station. Sky cover symbols are:

- O Clear: less than 0.1 sky cover
- ⦶ Scattered: 0.1 to less than 0.6 sky cover
- ⦶ Broken: 0.6 to 0.9 sky cover
- ⊕ Overcast: more than 0.9 sky cover
- \- Thin (when prefixed); light (when suffixed)
- -- Very light (when suffixed)
- -X Partial obscuration: 0.1 to less than 1.0 sky hidden by precipitation or obstruction to vision (bases at surface)
- X Obscuration: 1.0 sky hidden by precipitation or obstruction to vision (bases at surface)

Letter preceding height of layer identifies ceiling layer and indicates how ceiling height was obtained. Thus:

- A Aircraft
- B Balloon (pilot or ceiling)
- D Estimated height of cirriform clouds on basis of persistency
- E Estimated height of noncirriform clouds
- M Measured
- R Radiosonde balloon or radar
- U Height of cirriform ceiling layer unknown
- V Immediately following numerical value indicates a varying ceiling (also used with varying visibility)
- W Indefinite, sky obscured by surface base phenomenon. e.g. fog, blowing dust, snow

RELATIVE HUMIDITY (RH)

Reported in percent and computed from temperature and dewpoint.

VISIBILITY (VV)

Reported in kilometers.

WEATHER AND OBSTRUCTION TO VISION SYMBOLS

A	Hail	IF	Ice fog
AP	Small hail	K	Smoke
BD	Blowing dust	L	Drizzle
BN	Blowing sand	R	Rain
BS	Blowing snow	RW	Rain showers
D	Dust	S	Snow
E	Sleet	SG	Snow grains
EW	Sleet showers	SP	Snow pellets
F	Fog	SW	Snow showers
GF	Ground fog	T	Thunderstorms
H	Haze	ZL	Freezing drizzle
IC	Ice crystals	ZR	Freezing rain

CLOUD ABBREVIATIONS

Ac	Altocumulus	Cs	Cirrostratus
As	Altostratus	Cu	Cumulus
Cb	Cumulonimbus	Ns	Nimbostratus
Cc	Cirrocumulus	Sc	Stratocumulus
Ci	Cirrus	St	Stratus

WIND

Direction in ten's of degrees from true north, speed in meters per second (mps). A "0000" indicates calm. A "G" indicates gusty. A "Q" indicates squall. Peak speed of gusts, when reported, follows G or Q. The contraction WSHFT in remarks followed by time group (GMT) indicates wind shift and its time of occurrence.

Examples: 0109 is 010 degrees, 9 mps.
3607G11 is 360 degrees, 7 mps, peak speed in gusts of 11 mps.

MSG: Data missing in original source.

APPENDIX B

VISIBILITY LABORATORY CONTRACTS AND RELATED PUBLICATIONS

Previous Related Contracts:
F19628-73-C-0013, F19628-76-C-0004

PUBLICATIONS:

Duntley, S. Q., R. W. Johnson, and J. I. Gordon (1972), "Airborne Measurements of Optical Atmospheric Properties in Southern Germany", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 72-64, AFCRL-72-0255.

Duntley, S. Q., R. W. Johnson, and J. I. Gordon (1972), "Airborne and Ground-Based Measurements of Optical Atmospheric Properties in Central New Mexico", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 72-71, AFCRL-72-0461.

Duntley, S. Q., R. W. Johnson, and J. I. Gordon (1972), "Airborne Measurements of Optical Atmospheric Properties, Summary and Review", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 72-82, AFCRL-72-0593.

Duntley, S. Q., R. W. Johnson, and J. I. Gordon (1973), "Airborne Measurements of Optical Atmospheric Properties in Southern Illinois", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 73-24, AFCRL-TR-73-0422.

Duntley, S. Q., R. W. Johnson, and J. I. Gordon (1974), "Airborne and Ground-Based Measurements of Optical Atmospheric Properties in Southern Illinois", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 74-25, AFCRL-TR-74-0298.

Duntley, S. Q., R. W. Johnson, and J. I. Gordon (1975), "Airborne Measurements of Optical Atmospheric Properties in Western Washington", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 75-24, AFCRL-TR-75-0414.

Duntley, S. Q., R. W. Johnson, and J. I. Gordon (1975), "Airborne Measurements of Optical Atmospheric Properties, Summary and Review II", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 75-26, AFCRL-TR-75-0457.

Duntley, S. Q., R. W. Johnson, and J. I. Gordon (1976), "Airborne Measurements of Optical Atmospheric Properties in Northern Germany", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 76-17, AFGL-TR-76-0188.

Duntley, S. Q., R. W. Johnson, and J. I. Gordon (1977), "Airborne Measurements of Atmospheric Volume Scattering Coefficients in Northern Europe, Spring 1976", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref 77-8, AFGL-TR-77-0078.

Duntley, S. Q., R. W. Johnson, and J. I. Gordon (1978), "Airborne Measurements of Atmospheric Volume Scattering Coefficients in Northern Europe, Fall 1976", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 78-3, AFGL-TR-77-0239.

Duntley, S. Q., R. W. Johnson, and J. I. Gordon (1978), "Airborne Measurements of Atmospheric Volume Scattering Coefficients in Northern Europe, Summer 1977", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 78-28, AFGL-TR-78-0168.

Duntley, S. Q., R. W. Johnson, and J. I. Gordon (1978), "Airborne Measurements of Optical Atmospheric Properties, Summary and Review III", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 79-5, AFGL-TR-78-0286.

Fitch, B. W., T. S. Cress (1981), "Measurements of Aerosol Size Distributions in the Lower Troposphere over Northern Europe", University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 81-18, AFGL-TR-80-0192.

Gordon, J. I., J. L. Harris, Sr., and S. Q. Duntley (1973), "Measuring Earth-to-Space Contrast Transmittance from Ground Stations", Appl. Opt. 12, 1317-1324.

Gordon, J. I., C. F. Edgerton, and S. Q. Duntley (1975), "Signal-Light Nomogram", J. Opt. Soc. Am. 65, 111-118.

Gordon, J. I., (1979), "Daytime Visibility, A Conceptual Review", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 80-1, AFGL-TR-79-0257.

Johnson, R. W., and J. I. Gordon (1979), "Airborne Measurements of Atmospheric Volume Scattering Coefficients in Northern Europe, Winter 1978", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 79-25, AFGL-TR-79-0159.

Johnson, R. W., W. S. Hering, J. I. Gordon, B. W. Fitch, and J. S. Shields (1979), "Preliminary Analysis & Modelling Based Upon Project OPAQUE Profile and Surface Data", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 80-5, AFGL-TR-79-0285.

Johnson, R. W. and J. I. Gordon (1980), "Airborne Measurements of Atmospheric Volume Scattering Coefficients in Northern Europe, Summer 1978", University of California at San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 80-20, AFGL-TR-80-0207.

Johnson, R. W. (1981a), "Winter and Summer Measurements of European Very Low Altitude Volume Scattering Coefficients," University of California, San Diego, Scripps Institution of Oceanography, SIO Ref. 81-00, AFGL-TR-81-0154.

Johnson, R. W. (1981b), "Daytime Visibility and Nephelometer Measurements Related to its Determination", ATMOSPHERIC ENVIRONMENT, 15, 10/11, 1835.